Review on the Simulation of Cooperative Caching Schemes for MANETs

Francisco Javier González-Cañete, Eduardo Casilari
Department of Electronic Technology
University of Malaga
Campus de Teatinos, ETSI Telecomunicación, Málaga
SPAIN
{fgc,ecasilari}@uma.es

Abstract: - In this paper, a review of the main simulation parameters utilized to evaluate the performance of cooperative caching schemes in Mobile Ad Hoc Networks is presented. Firstly, a taxonomy of twenty five caching schemes proposed in the literature about Mobile Ad Hoc Networks is defined. Those caching schemes are briefly described in order to illustrate their basis and fundamentals. The review takes into consideration the utilized network simulator, the wireless connection standard, the propagation model and routing protocol, the employed simulation area and number of data servers, the number of mobile devices and their coverage area, the mobility model, the number of documents in the network, the replacement policy and cache size, the mean time between requests, the document popularity distribution, the TTL (Time To Live) of the documents and the simulation time. Those simulation parameters have been compared among the evaluation of the studied cooperative caching schemes in order to obtain the most common utilized values. This work will allow to compare the performance of the proposed cooperative caching schemes using a common simulation environment.

Key-Words: - Mobile Ad hoc networks, cooperative caching, performance evaluation

1 Introduction

Since the Mobile Ad Hoc Networks (MANETs) were proposed as a solution for deploying communication applications in places where a wired network was not available, many cooperative caching schemes have been proposed in order to enhance the performance of these kind of networks. This improvement is necessary because of the limitations of the MANETs:

- Restricted hardware capabilities. Some light weight devices are constrained in their processing and computing capabilities.
- Limited batteries. Mobile devices operate with batteries. In order to maximize their lifetimes, the number of messages that they generate should be moderated.
- Scarce bandwidth. Wireless medium has restricted bandwidth so signaling traffic should be minimized in MANETs.

Temporary connection to external networks. The integration of MANET into external networks is guaranteed through Gateways. However, the mobility of the MANET may provoke the Gateway to be temporarily unavailable.

Thus, the goals of a cooperative caching scheme are to decrease the protocol overhead in the network, to reduce the delay perceived by the users and to guarantee, as far as possible, the accessibility to the documents even when the external networks are not available. For these purposes, the scientific literature has proposed many different cooperative caching schemes which follow diverse approaches to deal with the network management. In this sense, these proposed cooperative caching schemes have been evaluated using a very wide range of parameters and metrics. In addition, papers do not always specify the full list of parameters employed to simulate the proposed caching strategies. Consequently, it is hard to simulate and compare different caching schemes using the same environment variables.

The objective of this paper is to study the trends in simulating cooperative caching schemes for MANETs, taking special attention to the gaps in the related literature. The definition of the usual parameters employed to evaluate the performance of the cooperative caching schemes will allow to compare their performance using a common simulation environment. To the best of our knowledge, this is the first work that compares the parameters utilized in the performance evaluation of the cooperative caching schemes in MANETs. The rest of this paper is structured as follows. In Section 2, a taxonomy and brief description of the analyzed caching schemes is presented. Section 3 details and compares the simulation parameters employed in order to evaluate the performance of the studied caching schemes. Finally, Section 4 outlines the main conclusion of this work.

2 Cooperative caching

In this section we will enumerate, classify and briefly describe the cooperative caching schemes for MANETs which have been proposed by the literature about caching in MANETs.

The cooperative caching schemes can be classified into four groups according to their behavior:

- Broadcast-based: the mobile terminals (MT) broadcast the requests in order to find another MT which can reply with the requested document.
- Information-based: the MTs interchange or store information about where the documents are located in the network
- Role-based: each MT has a specific function in the network, which can be organised in clusters. Depending on the architecture, some MTs are selected as information coordinators or clients.
- Direct-request: the requests are directly sent to the server.

Fig. 1 represents this taxonomy of the caching schemes. The above mentioned categories are commented in detail in the following sub-sections.

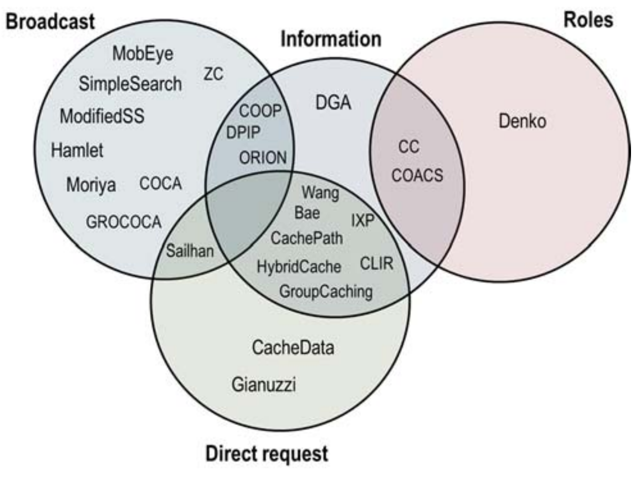

Fig. 1 Taxonomy of the caching schemes.

2.1 Broadcast-based caching schemes

The broadcast-based caching schemes employ a four message technique to obtain the requested documents. Firstly, the requester MT sends a broadcast message asking for the document. If another MT that has a valid copy in its local cache receives the request, it replies informing of that fact. When the requester receives this message it sends a unicast request to that intermediate MT, which in turn responds with the document.

The MobEye (MOBile intErcepting proxY cachE) [1] is a pure broadcast-based caching scheme as it sends all the requests using this mechanism. MobEye implements a LRU (Least Recently Used) replacement policy in the local caches. On the other hand, SimpleSearch [2] follows a more restrictive approach that limits the distance of the messages to four hops in order to reduce the traffic load. If the request is not satisfied after a predefined time, the petition is sent to the server using a unicast message. Additionally, SimpleSearch proposes three replacement policies for the local cache: TDS_D (Time and Distance Sensitive – Distance), which takes into account the distance to the MT that served the document, TDS_T (Time and Distance Sensitive – Time), which considers the time of the last reference of a document, and TDS_N (Time and Distance Sensitive – Neutral), which evaluates both the distance and the time of the last reference. ModifiedSS [3] is an evolution of SimpleSearch that employs GPS (Global Positioning System) in order to send the requests to the direction where the servers are located in order to reduce the traffic load caused by the broadcast messages. Hamlet [4] proposes to estimate the time that the documents must be stored in the local cache regarding the documents stored in the rest of the caches.

The COCA (COoperative CAching) [5] caching scheme divides the MTs into LAM (Low Activity Mobile host) and HAM (High Activity Mobile host). The server disseminates the most requested documents in the LAM terminals so that the HAM terminals could access them from a closer location. MTs ask for the documents by broadcasting request messages to their neighbours. If the solicited document is not found, it is directly requested to the server. GROCOCA (GROup-based COoperative CAching) [6] is a version of COCA that employs group creation being based on the mobility of the MT. Thus, the MTs request the documents to the rest of the MTs in their group before sending the requests to the server. To avoid the replication of documents in the same group, the groups maintain a unified cache.

Finally, Moriya[7] and Zone Cooperative Caching [8] strategies send the broadcast messages to the neighborhood so that, if the document is not found, the request is transmitted to the server. Every MT in the route to the server will look for the document in its own neighborhood before forwarding the request to the next MT in the route to the server.

2.2 Information-based caching schemes

The information-based cooperative caching schemes utilize information of the location of the documents in the network. Specifically, they store and exchange information about the MTs where the documents are stored.

As an example of pure information-based caching scheme we can mention DGA (Distributed Greedy Algorithm) [9]. This algorithm proposes to save, for every requested document in the network, the address of the closest MT that has a copy of the document. In addition, the address of the second closest MT is also stored. When a MT stores a document in its local cache, it sends an *AddCache* broadcast message informing to the other MTs about the new location of the document. Using this message, the rest of MTs update the information they manage.

2.3 Direct-request caching schemes

The direct-request caching schemes send the requests directly to the servers with the hope of being served by an intermediate MT in the route from the requester to the server.

The caching scheme proposed by Gianuzzi [10] is the best example of a pure direct-request caching scheme. On the other hand, CacheData [11] stores the documents in the local cache of the MTs that have to forward the replies to the requester. The intermediate MTs only store the documents if they are considered to be ‘popular’. In that way, the popular (most demanded) documents will be served by MTs that are located closer than the server.

2.4 Role-based caching schemes

The role-based caching schemes assign different roles to every MT in the ad hoc network. Consequently, they can be caching terminals, requesting terminals, coordinator terminals, gateway terminals, etc.

In the caching scheme proposed by Denko [12], the network is divided into clusters. Every cluster has a CH (Cluster Head) terminal that deals with the communication with other clusters, a DS (Data Source) terminal that stores the documents to be served, CA (Caching Agents) terminal that store documents in their caches and MH (Mobile Host) that request the documents. The MHs consecutively request the documents to its neighbours, to the CA, to the DS and, finally, to the CH. If the document is not found in any of them, the request is sent to another cluster using the CH terminal.

2.5 Hybrid caching schemes

Some caching schemes make use of mixed or hybrid approaches. In that way, they combine the previously commented techniques.

2.5.1 Broadcast and direct request

The caching scheme proposed by Sailhan [13] requests the documents to the server if it is in the coverage area of the requester. Otherwise, the document is requested to the neighborhood using a broadcast message. If this request is not replied, the MT performs the request to the server.

2.5.2 Information and direct request

The IXP (IndeX Push) [14] caching scheme manages a table called IV (Index Vector) that stores, for every document in the network, the address of the MT that has a copy of the document and how many copies of it are stored in the caches of the neighbor MTs. When a MT stores or deletes a document from its local cache, it sends a message to its neighborhood in order to maintain the IV tables updated. When a MT needs a document, it first checks the IV table for a nearby MT. If not found, the request is forwarded to the server. A MT in the route to the server can reply with the document if it has a copy in its local cache. In addition, it can also redirect the request using the information stored in the IV table.

The caching scheme proposed by Wang [15] sends the requests to the server if there is no information about the location of the requested document. Additionally, the document is stored in the middle of the route from the replier to the requester. Thus, the location information in the MTs of the route is also updated.

The CachePath [11] caching scheme stores the information about the location of the documents in the network if they are located closer (in number of hops) than the server. The requests can be redirected to a certain MT having the document if the difference between the distances to the server and to the MT is greater than a threshold value. On the other hand, HybridCache [11] is a mix of CacheData [11] and CachePath [11] that alternatively applies one or another algorithm depending on some heuristics. The caching scheme proposed by Bae [16] employs fuzzy logic in order to decide which caching scheme (CacheData or CachePath) to apply.

The GroupCaching [17] scheme proposes to form groups of MTs that exchange periodic information about the documents they store in their local caches. Consequently, when a MT requests a document it first verifies this table in order to send the request to a closer MT. Otherwise, the request is sent to the server.

Finally, the CLIR (Cross-Layer Interception and Redirection) [18] caching scheme employs the information that it collects from the forwarding messages in order to identify the location of the documents. Moreover, CLIR uses the underlying routing protocol to search the documents at the same time that the route to the server is created.

2.5.3 Broadcast and information

The caching scheme COOP [19] employs broadcast requests (limited to four hops) as the first choice to find the required documents. On the other hand, every MT has a table called RRT (Recent Request Table) that stores information of the location of the documents in the network. This information is obtained by analyzing the request and reply messages that are forwarded by the MTs. The MTs can perform the request to a certain MT if there is a related entry in the RTT table. If the requested document is not located using the broadcast messages and the RTT table, it is requested to the server.

The caching scheme DPIP (Data Pull/Index Push) [14] was proposed as an evolution of IXP. DPIP broadcasts the request to the neighbor MTs including information about the documents that will be evicted from the requester local cache. When a MT receives a document request and it has a valid copy of it, the document is served. On the other hand, if the MT has an entry in its IV table indicating the location of the document, it replies with the address of the MT that has the document.

The ORION (Optimized Routing Independent Overlay Network) [20] caching scheme works with two phases: search and transfer of documents. In the searching phase, the MTs compile location information by sending query messages. During the second phase, the MTs request the documents using the information collected in the previous phase.

2.5.4 Information and role

The CC (Cluster Cooperative) [21] caching scheme divides the network into clusters. Every cluster has a CSN (Cache State Node) that keeps updated information about the documents stored in the MTs of the cluster. The MTs periodically send descriptors about the content of their caches to the CSN. The requests are sent to the CSN that checks if it has information of the location of the document. If so, the CSN replies to the requester MT with the MT address that has the document. Otherwise, the CSN informs the requester MT that the request must be forwarded to the server.

Under the COACS (Cooperative and Adaptive Caching System) caching scheme [22], the MTs can adopt two possible roles: QD (Query Devices) or CN (Caching Nodes). The QD stores the location information of the documents and the CN stores the documents in their local caches. The requests are sent to the QD that replies with the document location. Otherwise, the request is redirected to another QD until the document is found.

3 Simulation of Cooperative Caching Schemes for MANETs

Due to the difficulty of both creating analytic models for MANET behavior and performing real tests on actual MANET networks, it is usual to study the performance of this kind of networks using simulators. In this section, a review of the simulation parameters used in the caching schemes for MANET evaluations will be presented.

In the tables shown in this section, the symbol "N/S" (Not Specified) is used when the used parameter is not known as it is not specified in the related paper. The symbol "NO" will be used if this parameter is not taken into account in the evaluation. On the other hand, the Wang [15] and Gianuzzy [10] caching schemes will not be taken into consideration as authors do not offer any kind of evaluation of them in the corresponding papers. Consequently, there are no simulation parameters.

3.1 Wireless connection standard, propagation model and routing protocol

The connection standard defines the physical and link layers of the OSI (Open System Interconnection) stack protocol. It specifies the working rules in a WLAN (Wireless Local Area Network) that is the type of network employed in the evaluation of cooperative caching. The bandwidth of the network is defined depending on the connection standard. Additionally, the propagation model characterizes the radio wave propagation as a function of the frequency, distance and other conditions. Finally, the routing protocol defines how the packets will be routed from their source to the destination. Table 1 shows the connection standards, the propagation models and the routing protocols employed by the literature to evaluate the performance of the studied caching schemes.

Ten of the studies do not specify the employed connection standard while the rest utilize 802.11 (without mentioning the version). Only Hamlet [4] and CLIR [18] state that they use 802.11b. On the other hand, only five of the papers specify the employed propagation model, being the Two-Ray Ground model [27] employed in four of them and the Free Space model [27] only in one.

AODV (Ad hoc On-demand Distant Vector) [28] is the most employed routing protocol for evaluating the caching schemes, followed by DSDV (Destination-Sequenced Distance-Vector Routing Protocol) [29] and ZRP (Zone Routing Protocol) [30]. Hamlet [4] does not use a routing protocol but it performs a broadcast at the MAC layer in order to find the routes. Finally, we can mention that six of the analyzed papers do not specify the employed routing protocol.

Table 1. Connection standard, propagation model and routing protocol

Caching scheme	Connection standard	Prop. model	Routing protocol
MobEye	N/S	TRG	AODV
Sailhan	802.11	N/S	ZRP
ZC	N/S	N/S	N/S
CC	N/S	N/S	AODV
DGA	802.11	N/S	DSDV
IXP	802.11	N/S	N/S
DPIP	802.11	N/S	N/S
CacheData	802.11	N/S	AODV
CachePath	802.11	N/S	AODV
HybridCache	802.11	N/S	AODV
COACS	802.11	N/S	DSDV
Denko	N/S	N/S	AODV
GroupCaching	802.11	N/S	AODV
Moriya	N/S	N/S	Dijkstra
Hamlet	802.11b	TRG	NO
SimpleSearch	N/S	N/S	ZRP
ModifiedSS	802.11	FS	N/S
COOP	802.11	N/S	AODV
ORION	802.11	TRG	AODV
COCA	N/S	N/S	N/S
GROCOCA	N/S	N/S	N/S
Bae	N/S	N/S	N/S
CLIR	802.11b	TRG	AODV

3.2 Simulation area and data servers

The simulation area (which is always considered to be a bi-dimensional space) is defined as the space where the MTs of the network are going to be located and, if they move, the region where their movements are going to be restricted. On the other hand, the number and location of the document servers will define the availability of the documents. Table 2 compiles the simulation areas as well as the number of servers and their location employed in the evaluation of the caching schemes in the literature.

The simulation areas can be classified into square and rectangular. The square simulation areas are employed by eleven of the twenty three studied caching schemes while ten of them use a rectangular area. There are two papers that do not specify the simulation area. We must emphasize that there is not a homogeneous size for the simulation area. The paper about MobEye [1] is an atypical case as it does not specify the simulation area but the relationship between the sides of the simulation area.

The studied caching schemes can be divided into several categories according to the number of servers and their location in the simulation area. Most of the caching schemes are evaluated using one or two servers except Moriya [7] and MobEye [1] that employ five and six respectively. GroupCaching [17] and ORION [20] do not consider servers so that the documents are distributed among the MTs. Taking into consideration the server's location, the caching schemes can be categorized into those where they are located in the corners of the simulation area (DPIP [14], IXP [14], CacheData [11], CachePath [11], HybridCache [11], COACS [22] and Hamlet [4]) and randomly located (MobEye [1], DGA [9], GroupCaching [17], ORION [20]). CLIR [18] is an exception as it places the servers in the center of the left and right side of the simulation area. Finally, we must mention that five of the caching schemes do not define the number of servers nor their location.

Table 2. Simulation area, number of servers and location

Caching scheme	Simulation area	Number of servers and position (x,y)
MobEye	N/S	6 (random)
Sailhan	4000 x 4000	N/S
ZC	1500 x 1500	1 (750, 750)
CC	1500 x 1500	1 (750, 750)
DGA	2000 x 500	2 (random)
IXP	1500 x 500	1 (0, 0)
DPIP	1500 x 500	1 (0, 0)
CacheData	1500 x 320	2 (0,0) (1500,320)
CachePath	1500 x 320	2 (0,0) (1500,320)
HybridCache	1500 x 320	2 (0,0) (1500,320)
COACS	1000 x 1000	1 (close to a corner)
Denko	1500 x 1500	N/S
GroupCaching	1500 x 500	Documents distributed among MTs
Moriya	600 x 600	5 MTs have all the documents
Hamlet	3000 x 3000	2 (3000,0) (0,3000)
SimpleSearch	3000 x 3000	1 (1500, 1500)
ModifiedSS	2000 x 750	1 (1000, 375)
COOP	1500 x 300	N/S
ORION	1000 x 1000	Documents distributed among MTs
COCA	500x500	1 (250, 250)
GROCOCA	1000x1000	1 (N/S)
Bae	N/S	N/S
CLIR	1000x1000	2 (0,500) (1000,500)

3.3 Mobile terminals and coverage area

The number of MTs in the network defines, together with the size of the simulation area, the density of MTs in the wireless network. The density of the MTs and the coverage area are parameters that characterize the network connectivity. In this sense, the more MTs per square meter and coverage area the more the connectivity probability among MTs.

The accessibility to the servers is determined by their location in the simulation area. The closer to the center of the simulation area, the more available coverage to connect to other MTs.

Table 3. Number of MTs, coverage area and probability of isolated servers

Caching Scheme	MTs	Coverage (meters)	Prob. Isolated server
MobEye	40	180	
Sailhan	500	250	
ZC	70	250	0.002
CC	70	250	0.002
DGA	100	250	
IXP	70	250	0.009
DPIP	70	250	0.009
CacheData	100	250	0.00002
CachePath	100	250	0.00002
HybridCache	100	250	0.00002
COACS	100	100	
Denko	200	250	
GroupCaching	100	100	
Moriya	50	90	
Hamlet	377	100	0.72
SimpleSearch	200	250	0.01
ModifiedSS	50	250	0.0009
COOP	100	250	
ORION	40	115	
COCA	100	50	0.04
GROCOCA	100	100	
Bae	N/S	N/S	
CLIR	50	250	0.08

Supposing that the (static) position of the MTs in the simulation area follows a uniform distribution, the probability that none of the MTs will be in the coverage area of a server can be calculated as shown in (1):

$$P(isolated) = \left(1 - \frac{\pi r^2 \cdot prop}{a \cdot b}\right)^n \qquad (1)$$

where r is the coverage area of the server, a and b are the width and height of the simulation area, n is the number of MTs that are not servers and prop is the coverage area proportion inside the simulation area. In the left case of Figure 2, prop=1 as the full coverage area is inside the simulation area. In the right case of Figure 2, prop=1/4. This calculus is performed assuming a single-ray LOS (Line-of-Sight) or a two-ray propagation model. These simplistic models are assumed in most studies about caching schemes in MANETs (Table 1).

Table 3 shows the default number of MTs employed to evaluate the studied caching schemes as well as their coverage area. In the table, the probability that the servers will be isolated is also specified for those cases when their position is fixed and known. As can be observed, there is a great disparity in the employed number of MTs, ranging from the 40 MTs used by MobEye [1] and ORION [20] and the 500 MTs contemplated by Sailhan [13]. The most common coverage area is 250 meters. On the other hand, the probability of isolated servers is between practically zero for CacheData, CachePath and HybridCache [11] and 0.08 for CLIR [18]. Hamlet [4] is the extreme case where this value is 0.72. The greater the probability of isolated servers, the greater the probability that MTs could not access them to obtain the documents.

3.4 Mobility model

The mobility model defines how the MTS will move along the simulation area, their speed and if they will stop and wait after another movement. Table 4 shows that information for the studied caching schemes.

As it can be noticed, all the caching schemes employ RWP (Random Way Point) [23] as mobility pattern. The only exception is the study that proposes the Hamlet scheme, which uses the IDM-IM (Intelligent Driver Model with Intersection Management) mobility model [24]. Additionally, Sailhan [13] and Bae [16] do not specify the employed model. Considering the speed of the MTs, random distributions are used although the speed range varies between 0 m/s and 20 m/s. Other caching schemes employ constant speed as ZC [8], CC [21], CacheData [11], CachePath [11], HybridCache [11], Morilla [7], Hamlet [4] and CLIR [18]. In the simulation of nine of the caching schemes, authors use a minimum speed of 0 m/s. This null speed has been proved to generate convergence problems in the simulations as the MTs could be indefinitely stopped if this speed is selected. In fact, if the simulation is longer enough (ideally infinite), the MTs will converge to a situation where all MTs will be stopped [25]. This implies that the results of all these simulations are skewed as long as the transitory is infinite. The pause time is also very disperse as it varies between 0 seconds and 300 seconds. Denko [12] and SimpleSearch [2] are special cases as they specify maximum pause values of 2000 and infinite respectively. Taking into account that the simulation time employed by Denko is 2000 seconds, both caching schemes evaluations could derive to a static network if the maximum value is selected. Finally, some caching schemes as GroupCaching [17], Hamlet [4] and Bae [16] do not specify this parameter in their performance evaluation.

Table 4. Mobility model parameters

Caching scheme	Mobility model	Default speed (m/s)	Pause time (s)
MobEye	RWP	Random [0.5, 1.38]	Rand. [0, 60]
Sailhan	N/S	N/S	N/S
ZC	RWP	2	300
CC	RWP	2	300
DGA	RWP	Random [0, 20]	300
IXP	RWP	Random [1, 20]	300
DPIP	RWP	Random [1, 20]	300
CacheData	RWP	2	300
CachePath	RWP	2	300
HybridCache	RWP	2	300
COACS	RWP	Random [0.01, 2]	100
Denko	RWP	Random [0, 20]	[200 – 2000]
GroupCaching	RWP	Random [1, 10]	N/S
Moriya	RWP	2	60
Hamlet	IDM-IM	6,94	N/S
SimpleSearch	RWP	Random [0, 1]	[0 – ∞]
ModifiedSS	RWP	Random [0, 2]	100
COOP	RWP	Random [1, 20]	120
ORION	RWP	Random [0, 2]	50
COCA	RWP	Random [0, 5]	1
GROCOCA	RWP	Random [0, 5]	1
Bae	N/S	N/S	N/S
CLIR	RWP	1	0

3.5 Documents, replacement policy and cache size

The number and size of the documents in the MANET and the cache size define the number of documents that could be stored in the local cache of the MTs. The greater the number of stored documents in cache, the greater the probability of benefiting from cache hits. Table 5 shows those values for the studied caching schemes.

As in the previous studies, there is not a consensus for choosing the simulation parameters. The number of documents in the network varies from 10 to a maximum of 10000. However, 1000 documents is the usual value. The size of the documents varies from 1 to 10 kB, being 1 kB the most employed value. We can remark that the papers about ZC [8], CC [21], DGA [9], CacheData [11], CachePath [11] and HybridCache [11] schemes use variable document sizes. However, the rest of caching schemes employs constant sizes. The most used replacement policy is LRU, except for those caching schemes that propose their own replacement policy. In this category we can mention Sailhan [13], ZC [8], CC [21], IXP [14], DPIP [14], CacheData [11], CachePath [11], HybridCache [11] and SimpleSearch [2]. On the other hand, Denko [12] employs the replacement policy LRFU [26]. We must emphasize that COACS [22], Moriya [7], Hamlet [4], ORION [20] and Bae [16] do not specify the employed replacement policy. Finally, the cache sizes are also very scattered as they vary from 1% to 30% of the size of the documents in the network.

Table 5. Number of documents and size, replacement policy and cache size

Caching scheme	Num. docs.	Size (kB)	Rep. policy	Cache size (kB)
MobEye	60	10	LRU	120
Sailhan	N/S	1	Sailhan	N/S
ZC	1000	[1, 10]	VALUE	800
CC	1000	[1, 10]	LUV-Mi	800
DGA	1000	[0.1, 1.5]	LRU	75
IXP	3000	1	CV	60
DPIP	3000	1	CV	60
CacheData	1000	[1, 10]	SXO	800
CachePath	1000	[1, 10]	SXO	800
HybridCache	1000	[1, 10]	SXO	800
COACS	10000	10	N/S	200
Denko	N/S	N/S	LRFU	100
GroupCaching	1000	10	LRU	200
Moriya	N/S	N/S	N/S	1024
Hamlet	10	1	N/S	10 %
SimpleSearch	1000	N/S	TDS_D TDS_T TDS_N	16
ModifiedSS	1000	10	LRU	10
COOP	2000	N/S	LRU	50
ORION	N/S	3096	N/S	N/S
COCA	1000	1	LRU	5 %
GROCOCA	10000	1	LRU	100
Bae	100	N/S	SXO	N/S
CLIR	1000	1	LRU	35

3.6 Time between requests, document popularity distribution, TTL of the documents and simulation time

In this section, the waiting time between requests, the traffic distribution, the TTL (Time To Live) of the documents and the employed simulation time to evaluate the caching schemes are studied. Table 6 summarizes those parameters for all the studied caching schemes.

The time between requests or waiting time between requests is defined as the mean time that MTs have to wait since they receive a document and a new request is performed. This waiting time is usually modelled using an exponential distribution. This mean waiting time is very variable from the evaluation of a caching scheme to another, with values from 1 to 6000 seconds for the most extreme cases. However, the most common values are in the range between 1 and 20 seconds.

The popularity of the documents is defined by a distribution that characterizes the particular documents that will be requested. In the analyzed caching schemes, the most employed distributions for the document popularity are the uniform distribution (for which all the documents have the same probability of being requested) and the Zipf distribution [31]. The Zipf law asserts that the probability P(i) for the i-th most popular document to be requested is inversely proportional to its popularity ranking as shown in equation (2).

$$P(i) = \frac{\beta}{i^{\alpha}} \tag{2}$$

The parameter α is the slope of the log/log representation of the number of references to the documents as a function of its popularity rank (i) while the β parameter is the displacement of the function.

In Table 6, the slope of the Zipf distribution has been specified using brackets in the column that indicates the popularity. As it can be observed, 0.8 is the most used value for the slope. On the other hand, the Zipf distribution is more employed than the random uniform distribution to evaluate the caching schemes.

Concerning the TTL of the documents, this parameter defines the time that they are considered valid in the simulation. Once the TTL has expired, the document is considered obsolete and its information is invalid. Only ten of the analyzed caching schemes take into account the expiration of the documents. The rest of caching schemes suppose that the documents are always valid and never expire. The employed TTL is usually specified using the mean value of an exponential distribution and the most common mean time is 5000 seconds. However, DGA [9] uses a uniform random value between 10000 and 20000 seconds while ModifiedSS [3] selects the value between 10 and 1000 seconds. The mean life time of the documents and the simulation time determine the mean number of times that the documents expire along the simulation so that they have to be requested again to the server as they are obsolete. Curiously, none of the analyzed caching schemes (except CLIR [18]) that take into consideration the TTL of the document specifies the simulation time.

Table 6. Time between requests (TBR), traffic distribution, TTL of the documents and simulation time

Caching scheme	**TBR (s)**	**Traffic**	**TTL**	**Sim. Time (s)**
MobEye	N/S	Unif.	NO	N/S
Sailhan	N/S	N/S	N/S	N/S
ZC	5	Zipf (0.8)	5000	N/S
CC	5	Zipf (0.8)	5000	N/S
DGA	10	Zipf (0.8)	Rand. [1000-2000]	N/S
IXP	20	Unif.	∞	5000
DPIP	20	Unif.	∞	5000
CacheData	5	Zipf (0.8)	5000	N/S
CachePath	5	Zipf (0.8)	5000	N/S
HybridCache	5	Zipf (0.8)	5000	N/S
COACS	10	Zipf	∞	2000
Denko	N/S	N/S	N/S	2000
GroupCaching	5	N/S	∞	6000
Moriya	200	N/S	∞	10000
Hamlet	[1000 – 6000]	Unif.	∞	N/S
SimpleSearch	600	Unif.	∞	N/S
ModifiedSS	[5 – 200]	Zipf (0.9)	[10-1000]	N/S
COOP	5	Zipf (0.8)	5000	N/S
ORION	N/S	N/S	∞	N/S
COCA	1	Zipf (0.5)	∞	20000 req.
GROCOCA	N/S	Zipf (0.5)	∞	20000 req.
Bae	10	Zipf (N/S)	300	N/S
CLIR	25	Zipf (0.8)	2000	20000

Only nine of the twenty three analyzed caching schemes specify the simulation time employed to evaluate their performance. The specified simulation time varies from 2000 to 20000 seconds, although COCA [5] and GROCOCA [6] do not specify and absolute simulation time, but the necessary time to perform 20000 requests.

4 Conclusion

In this paper, a taxonomy to classify and analyze twenty five caching schemes proposed in the literature about MANETs has been proposed. In addition, the studied caching schemes have been briefly described while the parameters used to evaluate the performance of the caching schemes have been investigated in order to obtain the most common utilized values.

The main conclusion that can be extracted by this work is that there is not a homogeneous way to evaluate the performance of the caching schemes as the default used simulation parameters are very heterogeneous. Additionally, most of the papers do not describe or specify the value of all the utilized parameters and even two of the caching schemes are not evaluated in their corresponding papers. Taking into consideration each studied parameter we can also conclude that:

- The square and rectangular simulation areas are employed practically in the same number of caching schemes. The number of servers also varies from one and two (the most common) to five or six. Additionally, some caching schemes do not use servers as the documents are distributed among the MTs.
- The number of MTs in the network is very variable (from 40 to 500 MTs) and the actual coverage transmission range is usually 250 meters.
- Random Way Point is the most employed mobility model. However the default speed of the MTs and the pause time are very heterogeneous.
- The usual number of documents in the network is 1000 with a default size of 1 kB. On the other hand LRU is the common replacement policy used by those caching schemes that do not implement their own replacement policy. There is not a common value of the size of the caches.
- 802.11 is the default connection standard used, although a great number of the papers do not specify the used standard. Moreover, the propagation model is not usually defined.
- AODV is the most employed ad hoc routing protocol.
- The waiting time between requests is very variable but the usual values range between 1 and 20 seconds. The popularity of the documents are usually modeled by the Zipf law although the uniform distribution is also employed. The value of the TTL of the documents usually follows an exponential distribution with a usual value of 5000 seconds. Finally, only a few caching schemes define the simulation time with values between 2000 and 20000 seconds. Those caching schemes that specify the TTL of the documents do not mention the value of the simulation time (except CLIR) and hence it is not possible to estimate how many times the documents will be obsolete.

Acknowledgements

We will like to thank Adela Isabel Fernandez Anta for revising the syntax and grammar of this paper. This work has been partially supported by the National Project No. TEC2009-13763-C02-01.

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